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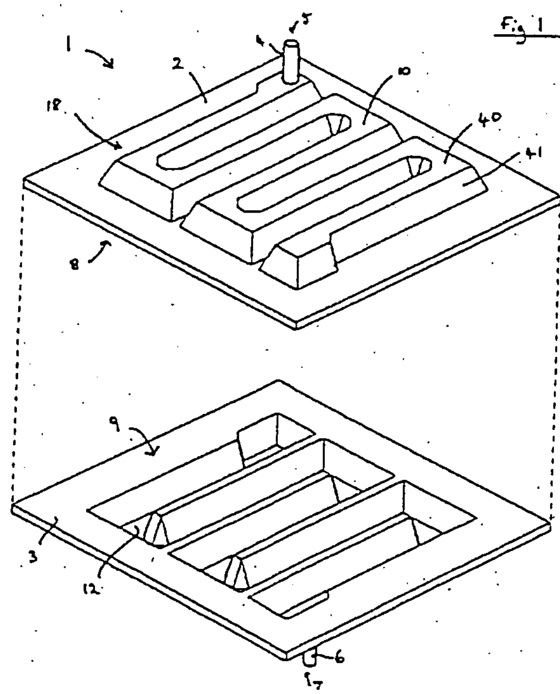
(54) Water heater with thick film printed circuit

(57) Heating apparatus comprises a vessel 1 formed by first and second stainless steel plates 2, 3 which are welded together in face to face contact. At least one of the plates is provided with an impressed formation 10 defining a serpentine impression which defines the chamber and extends between an inlet port 5 and an outlet port 7. A thick film printed circuit is applied to at least one of the plates to form electrically conductive tracks (14, 15, 16 Fig 2) which follow the serpentine path of the chamber. The circuit includes temperature sensors (24, 25) and current switching devices to regulate current through the tracks. The apparatus is intended for heating water in a domestic shower.

Fig 1



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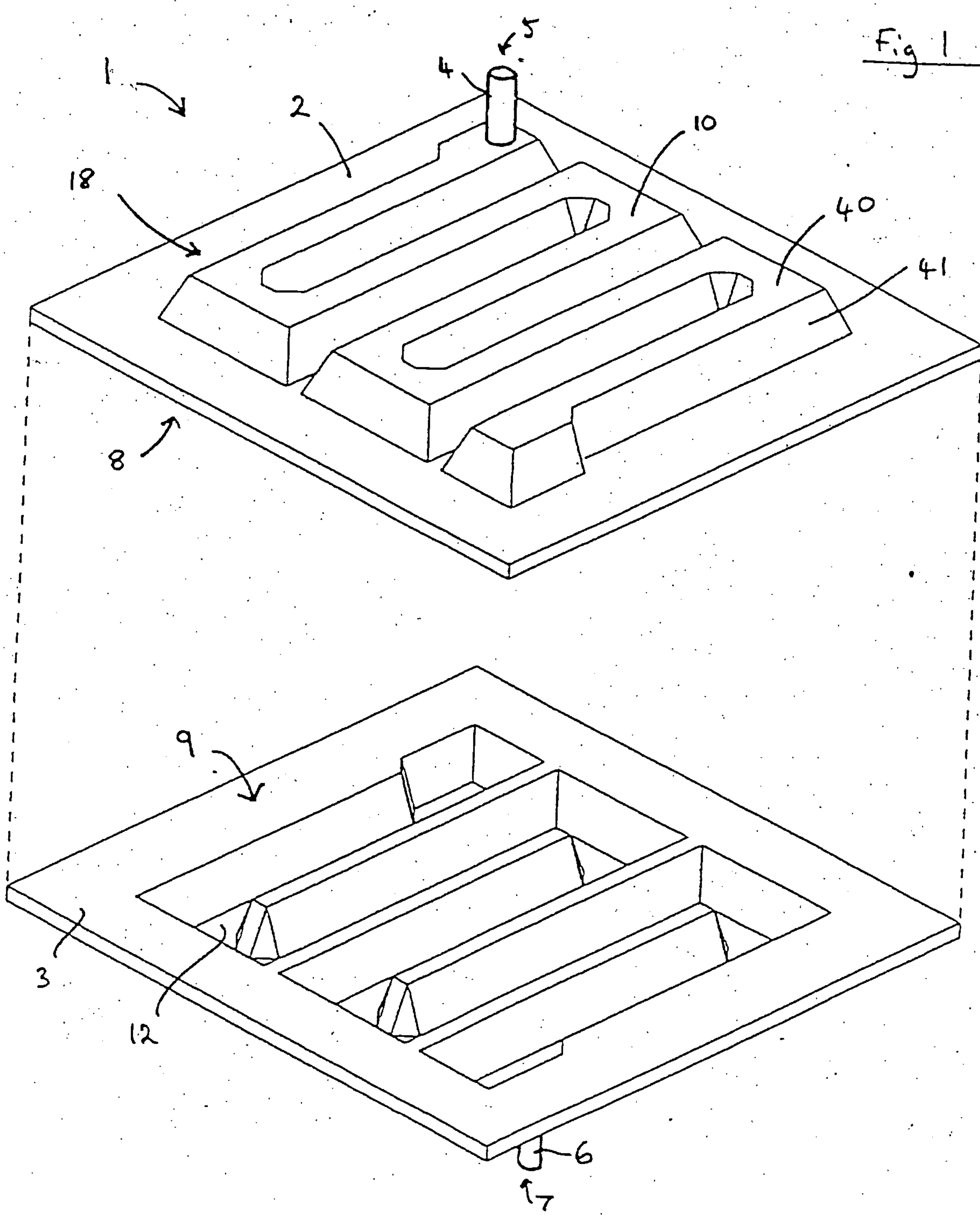


Fig 1

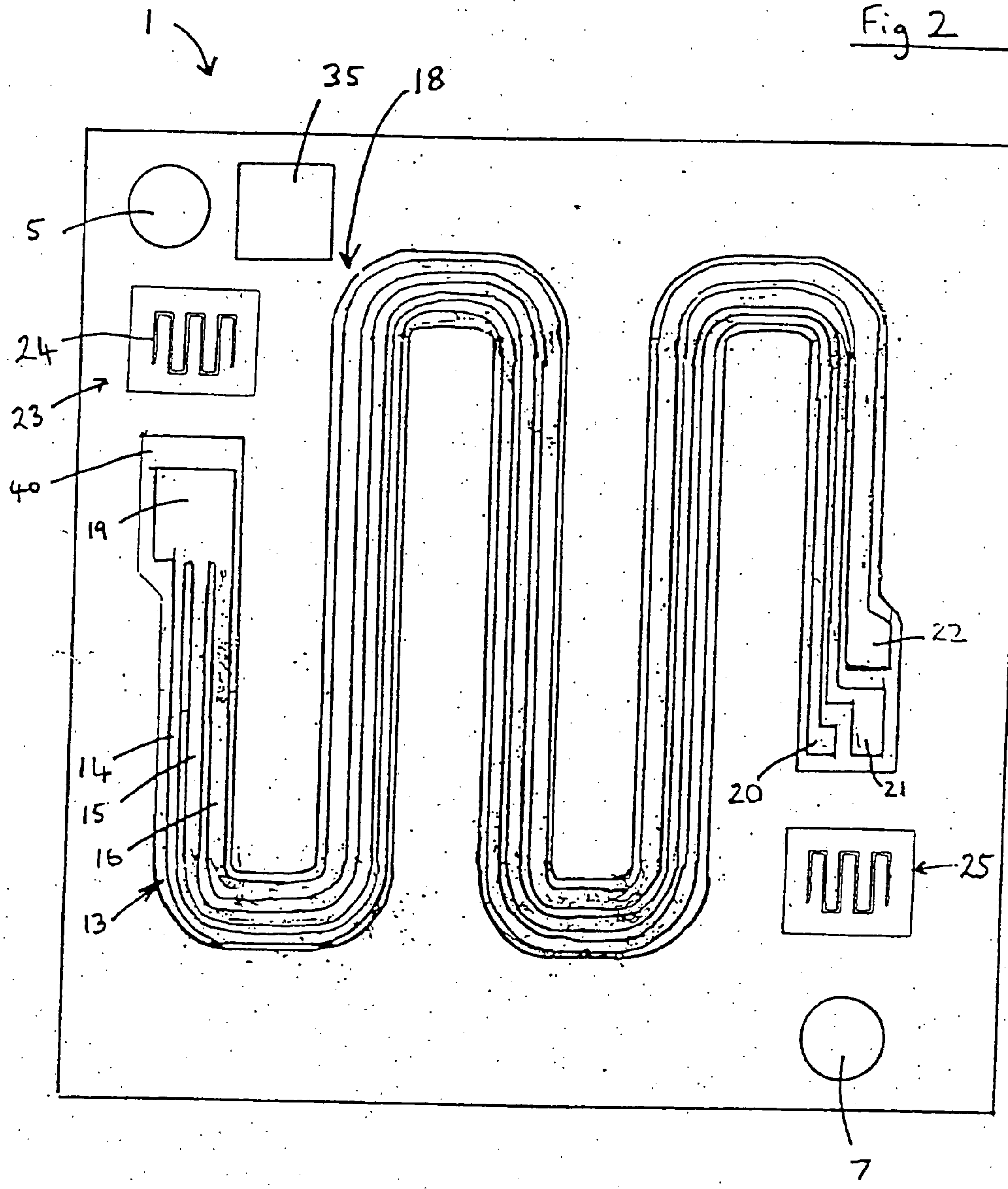


Fig 2

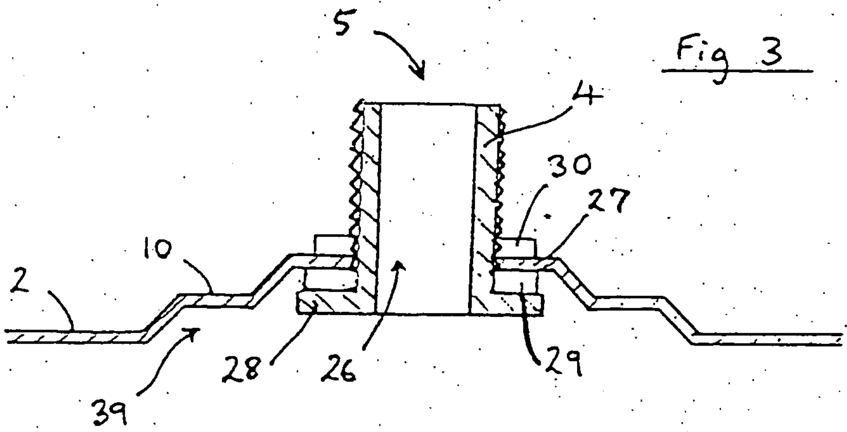


Fig 3

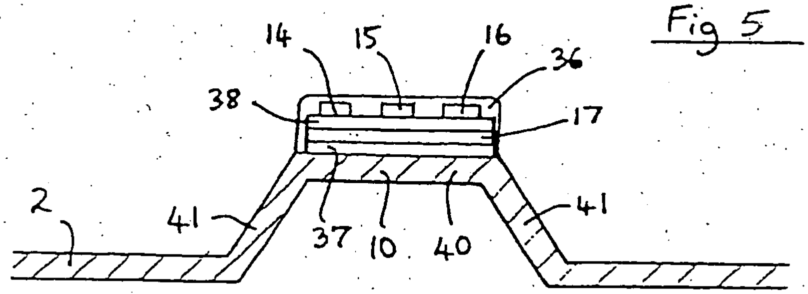


Fig 5

Fig 4

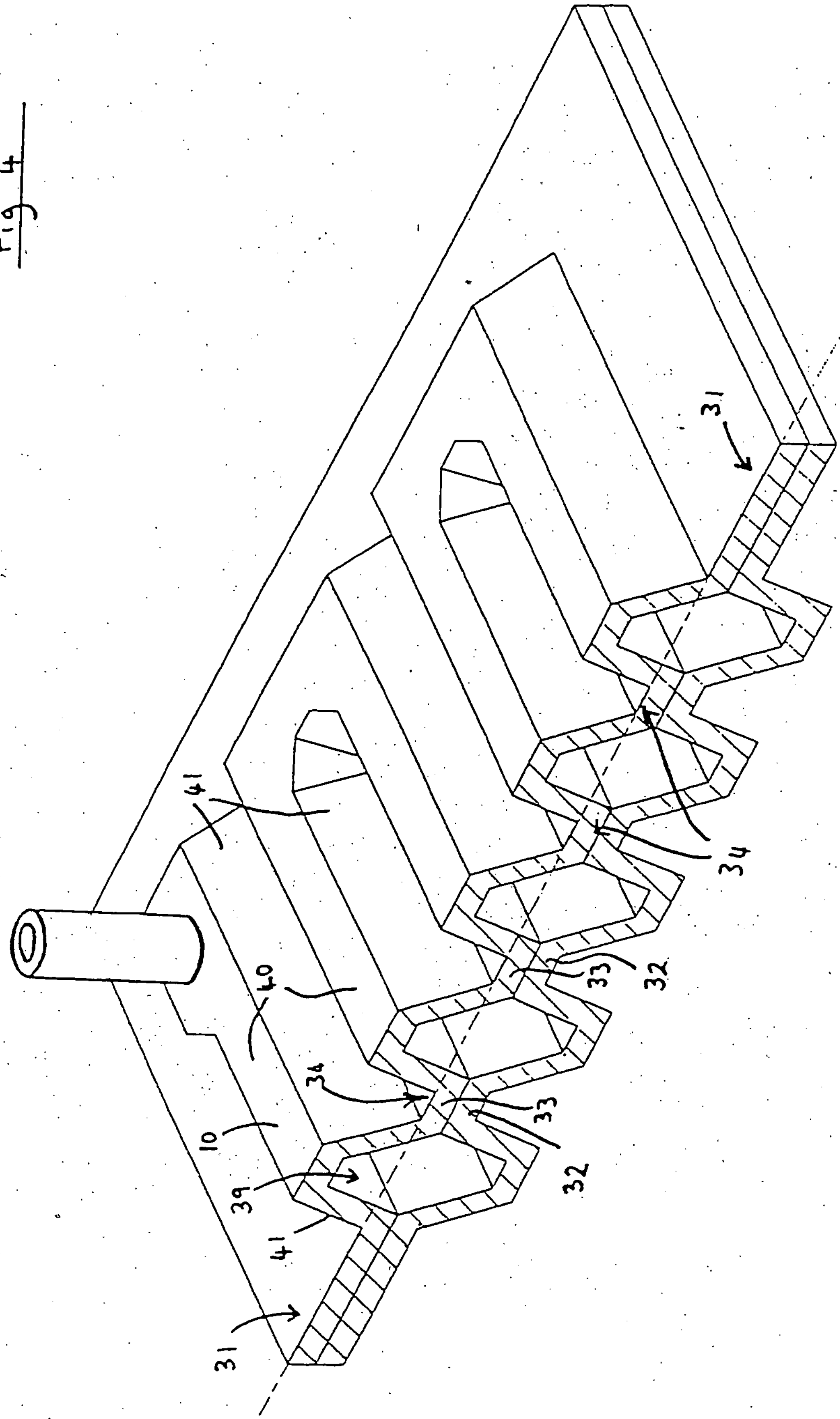
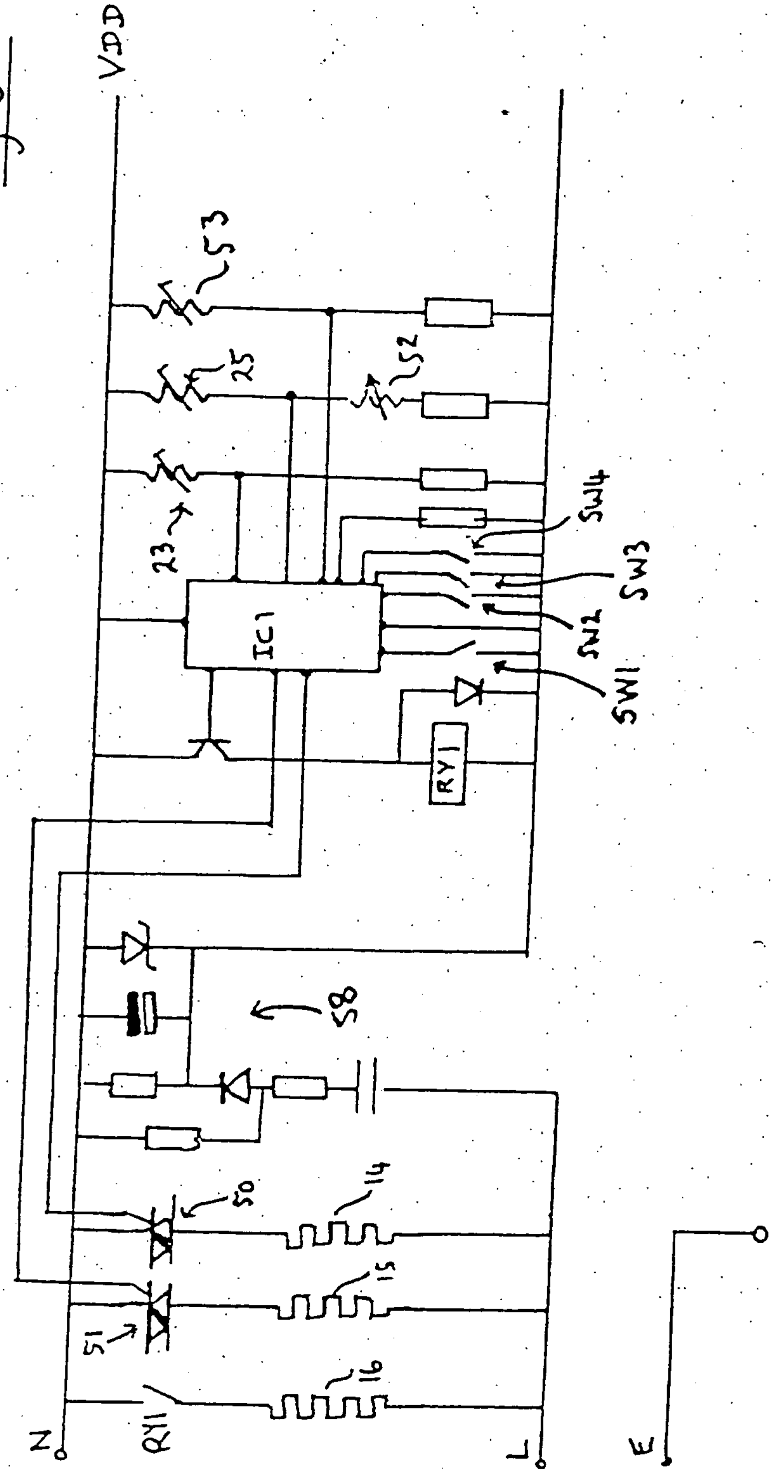


Fig 6



HEATING APPARATUS

This invention relates to heating apparatus for heating fluids and in particular but not exclusively to a hot water heater for use in a domestic shower.

It is known to provide water heaters in which a vessel defines a chamber through which fluid flows from an inlet to an outlet and which is provided with an electrical heating element. Such heating elements may be formed as electrically conductive tracks of a thick film printed circuit formed on a metal substrate constituted by a metal plate forming part of the vessel and defining a side wall of the chamber. EP-A-0485211 for example discloses such a hot water heating apparatus for use in a domestic shower in which a steel plate upon which the heating element is formed is assembled by screw fasteners to other components forming the vessel.

According to the present invention there is disclosed a heating apparatus comprising a vessel defining a chamber for conducting fluid to be heated and further defining an inlet port and an outlet port communicating with the chamber, the vessel comprising a metallic first plate, a heating element comprising at least one electrically conductive track of a thick film printed circuit formed on a metal substrate constituted by the first plate, a metallic second plate bonded to the first plate such that respective major faces thereof are in face to face contact and wherein at least one of the first and second plates comprises an impressed formation co-operating with the other of the plates to define the vessel therebetween.

An advantage of such apparatus is to simplify construction since the vessel can be formed by the basic operations of pressing the at least one plate to define the impressed formation and then bonding the plates together.

A preferred embodiment of the present invention will now be described by way of example only and with reference to the accompanying drawings of which;

Figure 1 is an exploded view of first and second plates together comprising a vessel;

Figure 2 is a schematic plan view of the first plate showing the thick film printed circuit;

Figure 3 is a sectioned elevation showing detail of an inlet port of the vessel of preceding Figures;

Figure 4 is a sectioned perspective view through the assembled vessel of Figure 1 showing detail of the impressed formations;

Figure 5 is a sectioned elevation showing schematically the formation of conductive tracks of the thick film circuit; and

Figure 6 is a circuit diagram of a circuit for powering the thick film printed circuit.

As shown in Figure 1 a heating apparatus 1 comprises a first plate 2 and a second plate 3, both being rectangular and formed of stainless steel.

An inlet pipe 4 is connected to the first plate 2 so as to define an inlet port 5 and an outlet pipe 6 is similarly connected to the second plate 3 to define an outlet port 7. The first and second plates 2 and 3 have major faces 8 and 9 respectively which abut one another in face to face contact when assembled in the complete apparatus. The first plate 2 has an impressed formation 10 formed by pressing the steel plate so as to deform a portion 40 of the plate constituting the impressed formation into a position in which it is spaced from the plane of the major face 8. An associated impression 39 is thereby defined by the impressed formation 10 so that the plates co-operate to define a chamber 11 as illustrated in Figure 4. The impressed formation 10 comprises a flat portion 40 parallel to the major face 8 and a peripheral ramped portion 41.

The second plate 3 is similarly provided with a second impressed formation 12 which in the configuration shown in Figure 1 projects downwardly to thereby enhance the width of the chamber 11.

As shown in Figure 2, a heating element 13 (not shown in Figures 1 and 4) is formed on the first plate 2 by a known technique of applying a thick film printed circuit to a metal substrate such that electrically conductive tracks 14, 15 and 16 extend over the upper surface of the first plate, being insulated from the plate by a dielectric layer 17 applied to the flat portion 40 as illustrated in Figure 5.

The tracks 14, 15 and 16 define a serpentine path 18 extending between a common terminal pad 19 adjacent the inlet port 5 and separate terminal pads 20, 21 and 22 adjacent the outlet port 7.

The first and second impressed formations 10 and 12 similarly follow the path 18 and extend around the locations of the inlet and outlet ports 5 and 7 such that the chamber 11 communicates with the inlet and outlet ports in a manner which defines a liquid flow path following the path 18.

It will therefore be apparent that fluid following the path 18 through the chamber 11 will be progressively heated by operation of the heating element 13.

A first temperature sensor 23 is formed on the first impressed formation 10 immediately adjacent the inlet port 5 and is constituted by a thermistor track 24 printed as part of the thick film printed circuit on a substrate constituted by the first plate 2. A second temperature sensor 25 of corresponding construction is similarly formed and located adjacent the outlet port 7. It will therefore be apparent that the temperature at the inlet and outlet ports 5 and 7 can be sensed by operation of the first and second temperature sensors 23 and 25 by sensing the respective resistance of the thermistor tracks constituting the sensors. In this way the inlet

water temperature and outlet water temperature can be monitored.

The first plate 2 is assembled with the inlet pipe 4 as illustrated in Figure 3. The first impressed formation 10 is provided with a circular hole 26 and an annular portion 27 peripheral to the hole is further raised in a direction away from the major face 8 to accommodate a retaining flange 28 projecting radially from the inlet pipe 4. A sealing gasket 29 inserted between the flange 28 and the annular portion 27 ensures water tight connection, a threaded nut 30 being threadingly connected to the pipe 4 to secure the inlet pipe in position with the gasket under compression.

The fitting and construction of the outlet pipe 6 corresponds to that of the inlet pipe 4.

As shown in Figure 4, the first and second plates 2 and 3 are bonded together in face to face contact. A continuous peripheral seam weld 31 bonds the peripheries of the plates 2 and 3 together in water tight sealed manner. As shown in the sectional view of Figure 4, abutting intermediate portions 32, 33 of the first and second plates respectively form barriers preventing direct through flow of liquid. These barriers need not be entirely water tight since in practice the liquid will take the path of least resistance through the larger cross sectional channel defined by the chamber 11. It is therefore sufficient to bond together the intermediate portions 32 and 33 by spot welds 34 at selected locations sufficient to maintain the plates in contact.

Figure 5 shows schematically and not to scale the way in which the thick film printed circuit is formed on the first plate 2 so as to be localised on the first impressed formation 10.

The dielectric layer 17 is a composite layer of graded thermal coefficient of expansion. The dielectric layer includes a first layer 37 in contact with the stainless steel first plate 2 and which has substantially

the same coefficient of thermal expansion as the steel. The composite dielectric layer 17 also includes an outer layer 38 having substantially the same coefficient of thermal expansion as the tracks 14, 15 and 16.

As illustrated schematically in Figure 2, a control circuit 35 including current regulating discreet components such as Triacs is mounted on the thick film printed circuit, thereby constituting a hybrid thick film printed circuit, resistive elements of the circuit being formed during the printing of the thick film printed circuit itself.

The thick film printed circuit as shown in Figure 5 also includes an encapsulation layer 36 effecting electrical isolation for safety purposes.

The plates 2 and 3 are formed in a process in which they are cut to size and then pressed to form the impressed formations 10 and 12 and the annular portions 27. The holes 26 are punched or drilled in registration with the annular portions 27. During the pressing operation, the edges of the plates are formed in preparation for seam welding at a later stage.

The blank steel plates 2 and 3 are then cleaned and subjected to a high temperature process to enrich their surface layers with a defined chromium oxide layer. This oxidization process is carried out at a peak temperature of between 750° and 960°C for timed periods of between five and fifteen minutes dependent on the type of steel being used.

The plates are then printed, dried and fired with successive layers of dielectric material, typically up to five layers of dielectric material of graded coefficient of thermal expansion being deposited to form a composite layer on to which the circuit is to be printed. The thick film printed circuit is then printed using a silk screen printing method in which thick film printing inks are deposited so as to define the tracks 14, 15 and 16,

the temperature sensors 24 and 25, the conductor pads 19, 20, 21, and 22 and the control circuit 35.

The inks are dried and fired using a profiled high temperature of between 600° and 800° C depending on the materials being processed.

Finally an encapsulating layer 36 is externally applied for insulation purposes.

The first and second plates 2 and 3 are assembled with the fittings consisting the inlet and outlet pipes 4 and 6 and presented in face to face contact. The spot welding processes is then carried out in which intermediate portions 32 and 33 of the first and second plates are bonded together, selective outer portions of the plates also being spot welded as may be required to achieve a robust assembly.

Finally the plates 2 and 3 are peripherally seam welded at seam welds 31 in Figure 4 to complete the construction of the apparatus 1.

Alternatively, the dielectric layer 17 may be applied to the plate 2 by an electro-static spraying technique using a suitable masking template. Rechrystalisable glass power is suitable for use in such a process.

The tracks 14, 15 and 16 may be formed from various materials ranging from Ruthenium through to doped base metals such as Silver, Copper, Gold or Nickel. The required power consumption of the heater element primarily determines the choice of material.

In the above preferred embodiment, three separate heating tracks 14, 15 and 16 are provided and can be individually energised via connections made to the pads 19, 20, 21 and 22. In this way low, medium and high rates of power dissipation can be readily selected using individual switching of the heater tracks 14, 15 and 16. This technique has the advantage of requiring relatively low current values to be switched thereby enabling relatively low cost switching devices to be utilised in

the control circuit 35. A further advantage is that mains interference effects associated with high current switching are reduced, thereby facilitating compliance with current switching regulations for domestic appliances.

In the preferred embodiment, the first, second and third tracks 14, 15 and 16 comprise 0.8 Kw, 1.2 Kw and 7 Kw consumption respectively with the first and second tracks being controlled by low cost 5 and 10 amp Triacs 50 and 51 respectively as shown in Figure 6. The relatively high power rated third track 16 is switched using a relay RY1, the third track typically being continuously engergised during any period in which the apparatus is turned on and one or both of the remaining first and second tracks selected to effect temperature control using the corresponding Triac or Triacs to continuously vary the rms current through the tracks.

A control circuit is illustrated in Figure 6 in which processor IC1 controls the amount of current delivered to the first, second and third tracks 14, 15 and 16 in response to user commands which are input by setting switches SW1, SW2, SW3 and SW4. A further user input is provided by a water temperature control potentiometer 52. SW1 is used to input on/off commands for the apparatus as a whole. SW2, SW3 and SW4 are utilised for selecting high, medium and low temperature ranges.

In Figure 6 the first and second temperature sensors 23 and 25 are shown as thermistors connected to the processor IC1. A third temperature sensor 53 is also shown to be connected to the processor IC1 and corresponds to a further printed track (not shown) on the plate 2 which is arranged to sense over-temperature or boil-dry situations.

The circuit of Figure 6 also includes a power supply section 58 which derives a stablised voltage VDD from AC mains input by means of a rectifier and a zenor diode.

The volumetric flow of water may alternatively be varied in order to maintain a constant water outlet temperature. An electronically controlled flow valve may for example be included upstream or downstream of the vessel to regulate flow. Flow may alternatively be regulated using a mechanical valve which has a temperature responsive element such as a bi-metal strip.

The temperature sensors 23 and 25 may also be connected to a monitoring circuit operable to turn off the current to the heater tracks if an excess temperature is sensed. Such a fault condition can arise if there is a sudden loss of water pressure in the supply. Alternatively, a bi-metal or other form of thermal cut out may be incorporated into the circuitry of the apparatus.

As a further alternative, bi-metal temperature switches may be utilised to regulate water temperature by switching current to one or more of the heating tracks.

It has been found that apparatus constructed in accordance with the preferred embodiment can withstand water pressure of 150 PSI.

Apparatus in accordance with the present invention may be modified to deliver power levels ranging from 3 Kw to 50 Kw. For higher power applications, it would be appropriate to construct the second plate so as to have corresponding heater elements to the heater elements 14, 15 and 16 of the first plate.

The construction of the apparatus may be modified for example by pressing only the first plate 2 to form an impressed formation defining the serpentine path, the second plate remaining planar. This configuration may be further modified by forming the heater tracks only on the second plate.

In the preferred embodiment, it would also be possible to carry out the pressing stage after the printing of the thick film printed circuit on those areas

of the plate which would subsequently constitute the impressed formations.

The Triacs used for power control may alternatively be replaced by any suitable power switching semi-conducting devices.

Claims

1. Heating apparatus comprising a vessel defining a chamber for conducting fluid to be heated and further defining an inlet port and an outlet port communicating with the chamber, the vessel comprising a metallic first plate, a heating element comprising at least one electrically conductive track of a thick film printed circuit formed on a metal substrate constituted by the first plate, a metallic second plate bonded to the first plate such that respective major faces thereof are in face to face contact and wherein at least one of the first and second plates comprises an impressed formation co-operating with the other of the plates to define the chamber therebetween.

2. Heating apparatus as claimed in claim 1 wherein the impressed formation defines a serpentine flow path of the chamber extending between the inlet port and the outlet port.

3. Heating apparatus as claimed in claim 2 wherein the tracks extend along a corresponding path to the serpentine flow path defined by the impressed formation.

4. Heating apparatus as claimed in claim 3 wherein the tracks are formed on the impressed formation.

5. Heating apparatus as claimed in any preceding claim wherein the first and second plates are peripherally bonded together by means of a seam weld.

6. Heating apparatus as claimed in any preceding claim wherein the plates are bonded together by spot welds.

7. Heating apparatus as claimed in any preceding claim wherein the thick film printed circuit comprises first and second temperature sensors located adjacent the inlet and outlet ports respectively.

8. Heating apparatus as claimed in any preceding claim wherein the thick film printed circuit further

comprises a control circuit located adjacent the inlet port.

9. Heating apparatus as claimed in any preceding claim wherein both the first and second plates comprise respective first and second impressed formations co-operating to define a serpentine flow path of the vessel extending between the inlet port and the outlet port.

10. Heating apparatus as claimed in any preceding claim wherein the heating element comprises a plurality of electrically conductive tracks connected to a control circuit such that current flowing through the respective tracks is independently switchable.

11. A method of forming a heating apparatus comprising metallic first and second plates forming a vessel defining a chamber for conducting liquid between an inlet port and an outlet port of the vessel, the apparatus further having a heating element comprising a thick film printed circuit formed on a substrate constituted by the first plate; the method comprising the steps of forming an impressed formation in at least one of the first and second plates and bonding the plates together in face to face contact such that an impression associated with the impressed formation defines the chamber.

12. A method as claimed in claim 11 wherein the impressed formation defines a serpentine flow path of the chamber extending between the inlet port and the outlet port.

13. A method as claimed in claim 12 including the step of printing the thick film printed circuit on at least the first plate such that electrically conductive tracks constituting the heating element extend along a path corresponding to the serpentine flow path defined by the impressed formation.

14. A method as claimed in claim 13 including the step of forming the tracks on the impressed formation.

15. A method as claimed in any of claims 11 to 14 including the step of peripherally seam welding the first and second plates together.

16. A method as claimed in any of claims 11 to 15 including the step of spot welding the first and second plates together.

17. A method of operating apparatus as claimed in claim 10 comprising the steps of supply current to a first track of the heating element continuously during periods when the apparatus is turned on and regulating the temperature of liquid heated by the apparatus by switching of current supplied to one or more additional tracks of the heating element.

18. A method of regulating the supply of electrical power to a heating apparatus comprising a vessel defining a chamber for conducting fluid to be heated and a plurality of heating elements comprising electrically conductive tracks of a thick film printed circuit;

the method comprising the steps of energising a relatively high power rated element of the heating elements continuously during a period in which heating is required, sensing the temperature to which the fluid is heated, and selectively energising one or more relatively low power rated elements of the heating elements by variably controlling electrical current supplied thereto.

19. A method as claimed in claim 19 wherein the relatively low power rated elements comprise a plurality of elements of different power rating.

20. A method as claimed in any of claims 18 and 19 wherein the power to the relatively low powered elements is controlled by means of respective power switching semi-conducting device.

21. Heating apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

22. A method of forming a heating apparatus substantially as hereinbefore described with reference to the accompanying drawings.

23. A method of operating heating apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.